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The automatic flagging of the quality of products generated by Autosat-2

by

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ABSTRACT

A preliminary scheme for detecting and reporting a number of characteristic errors in certain image products generated by Autosat-2 has been developed. It would be straightforward to refine the scheme to allow the quality of other image areas and other image types to be assessed, and other image defects to be detected.

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1 Abstract

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2 Introduction

For many years, the use of satellite imagery products was confined to visual interpretation by human experts. Even applications aimed at providing information for numerical weather prediction (NWP) models usually involved a stage in which humans interpreted the imagery. In doing so, it was possible for errors in the data to be filtered extremely effectively: the experts were able to identify regions of poor quality data resulting from a number of possible causes by comparing images with their idea of what the image should look like. This is, of course, a powerful and immensely subtle process, the subtlety only becoming truely apparent when one attempts to automate it!

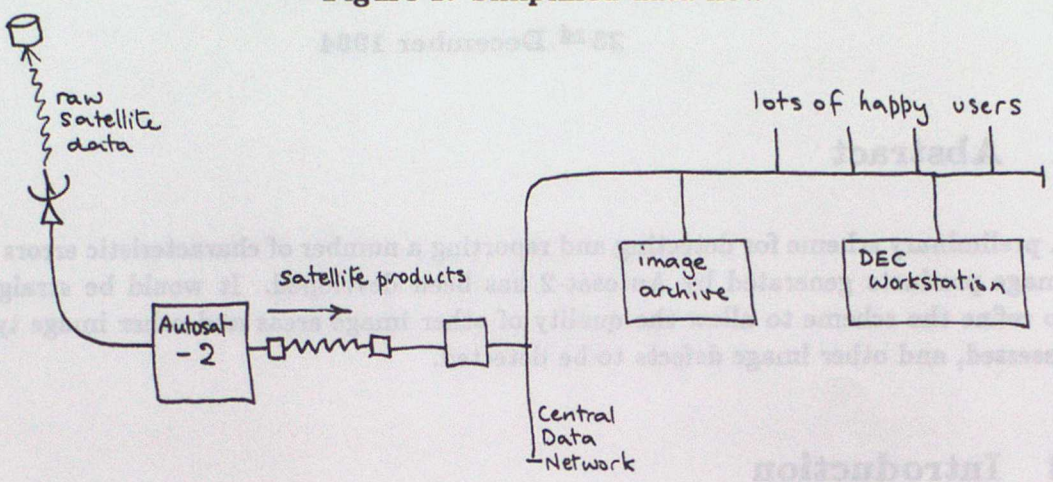
Increasingly, there are demands for different uses of satellite imagery, including its automatic use in NWP without the benefits of visual quality control and human interpretation. On the assumption that the quality of a model's analysis of, for example, cloud fields depends on the quality of the observational data that are used to generate it, it seems clear that as many of the faults in the satellite imagery as possible should be detected and flagged or corrected before being presented to the model's assimilation scheme.

The purpose of the study reported in this note is to identify as many errors as possible in the satellite imagery currently generated by the Office's Autosat-2 system and suggest methods whereby they might be detected automatically. It was not possible within the scope of the study to investigate all of the many Autosat-2 products. Only infra-red products from Meteosat on an area covering north-west Europe were considered. Although it is believed that the problems found in these images and the techniques determined to detect them will be of general applicability, further development and testing of the methods is considered inevitable.

3 Data flows

The flow of data used for this study is shown in figure 1.

Figure 1: Simplified data flow



Some of the image products generated by Autosat-2 are passed to the CHAOS computer system, where a subset of them is archived[1]. The Meteosat images used for the study form part of this subset. For convenience, the study was performed using data accessible directly, but potentially the scheme developed would be usable with the archived images also.

It is important to note that the Autosat-2 system performs a number of key functions intended to add value to the imagery products, particularly by making the information within them easier to assimilate by the forecasters for whom the bulk of the products were originally intended. These processes include navigation and remapping to a common projection and map area, calibration to physical quantities and in some cases, further physical interpretation, such as cloud detection.

Each of these processes can result in errors in the final products. It should also be noted that the process of receiving the data at the ground station can result in errors in the final products.

4 Method

4.1 General remarks

The study proceeded as follows. Firstly, sequences of the basic reprojected Meteosat infrared images were studied visually using standard image enhancing techniques to assist the detection of any problems in the images. Differences in the quality of the images from that considered to be desirable were noted (see below). Automatic techniques for detecting these errors were developed using PV-WAVE Command Language and tested.

[1] Potential users of satellite imagery products are welcome to contact the Satellite Imagery Applications Group for more information about this archive.

4.2 Problems with imagery

The following problems were discovered, although it should be noted that they are all rather rare events.

Missing data Rarely, data corresponding to large areas of an image will not be received correctly from the satellite (for various reasons) and therefore are unavailable to be used to generate the image product. Autosat-2 detects that this has happened and inserts a single "missing-data" value ie 255. Visually, such areas are obvious! Small numbers of lines have a curved appearance in the reprojected images; larger areas have similarly curved boundaries, where these exist.

Missing lines Occasionally, data corresponding to a small number of lines or half-lines are not received correctly from the satellite. Autosat-2 detects that this has occurred and responds by duplicating the last available line. There is a limit to the number of lines which can be corrected using this process, after which the data are treated as being "missing" (see above). The corrected lines are often difficult to detect visually, except when a large number of lines have been repeated. They are curved in the reprojected images.

Noise All image data has extraneous noise, some inherent in the collection process, some added during pre-processing, especially by the somewhat crude (but efficient!) resampling methods used for reprojection in Autosat-2. Some examples of the imagery showed what appeared to be quasi-periodic noise, similar to that sometimes seen in imagery from channel 3 of AVHRR data, but with a much lower intensity. Other noise occurs more randomly and is more evident in areas of low image contrast.

Navigation Two main process are involved: the basic image rectification (performed centrally at ESOC) which centres each raw image into a standard position to compensate for the slight fluctuations in the orbit of the satellite from the pure geosynchronous position, and the reprojection to a standard map. For the Meteosat images used in this study, no significant problems were detected in this respect. However, it should be noted that image navigation for AVHRR data is a more complex process; it is known that there are systematic problems which warrant attention.

4.3 Detection methods

The methods developed to detect errors have been implemented in PV-WAVE, currently as an interactive program so that the results from the tests can be checked against the visual appearance of the imagery. It was envisaged that a number of appropriate variables associated with the tests could be reported and stored as metadata for use in conjunction with the image archive or could be used in real-time to flag problems in current imagery.

One important distinction became apparent as the methods were being developed: those problems that were not related to the spatial arrangement of the pixels being investigated and those that were.

The former group includes the test for large areas of missing data. The relative frequency of occurrence of the "missing data" value in the standard reprojected image is calculated. A threshold value could be chosen to reject images that contain insufficient real data: presumably the threshold would depend upon the requirements of the intended application. Other values that might be useful to compute and store could include the mean and variance of the pixel values, and perhaps their frequency distribution.

The latter group involves a more sophisticated analysis mainly because the primary causes of the image defects are based on the geometry of the space-view data rather than the reprojected image products actually being analysed. A method of detecting repeated lines that are sharply curved was sought, but nothing suitable was found.

The problem was solved by reprojecting the image back into its original space-view using the inverse of the same process used on Autosat-2 to perform the initial remapping. Adequate speed was obtained by using a look-up table to store the mapping between the reprojected image and its original space-view. Any repeated lines would be straight and therefore much easier to detect by comparing adjacent lines. It also became feasible to quantify the levels of noise in the raw data lines.

However, an additional problem arose from an improvement that was made in the infra-red calibration for Meteosat images. The conventional methods used produced images for which the pixel values were linear in brightness temperature (as required) but yielded frequency distributions that were not sufficiently smooth. For example, some pixel values were not used while others were populated by excessive numbers of pixels. An improvement was made by adding a small amount of random noise during the calibration process: this had no effect on the visual appearance but produced a much smoother and "realistic" frequency distribution.

For the current study, however, this was a problem since it was no longer possible simply to identify adjacent lines that were identical. All lines would be different to a certain extent because the original data had been changed by the addition of the random noise. Thus, it was necessary to measure the difference between adjacent lines and to seek appropriately sensible limits to this difference.

A number of schemes were evaluated. It was necessary to reject linear correlation and root-mean-square error as measures of the difference between lines because they were not sufficiently sensitive. In fact, it was discovered that in regions containing homogeneous cloud, the root-mean-square difference between two adjacent lines was about the same as for identical lines. The best measure of the difference between adjacent lines was eventually found to be the range of the inter-line differences. The difference in value is computed between each pixel in one line and the corresponding pixel in the next; the range is the difference between the largest inter-line difference and the smallest. Using the range in this way focusses on the extremes of the distribution of the inter-line differences, making the test more sensitive than one based on the characteristics of the whole line.

In the tests performed, it was found that values of below 6.5 indicated a pair of near-identical lines, corresponding to exactly duplicated lines in the raw satellite data. An example is shown in figure 2.

5 Conclusions

A preliminary scheme for detecting and reporting a number of characteristic errors in certain image products generated by Autosat-2 has been developed. A number of refinements and further tests would be necessary to expand the applicability of the scheme, for example to other image area and to other image types.

The scheme provides a foundation for other examinations of image quality. For example, it would be straightforward to develop methods of quantifying noise, perhaps through the use of Fourier methods, and hence of correcting for them.

Figure 2: Part of standard Autosat-2 product

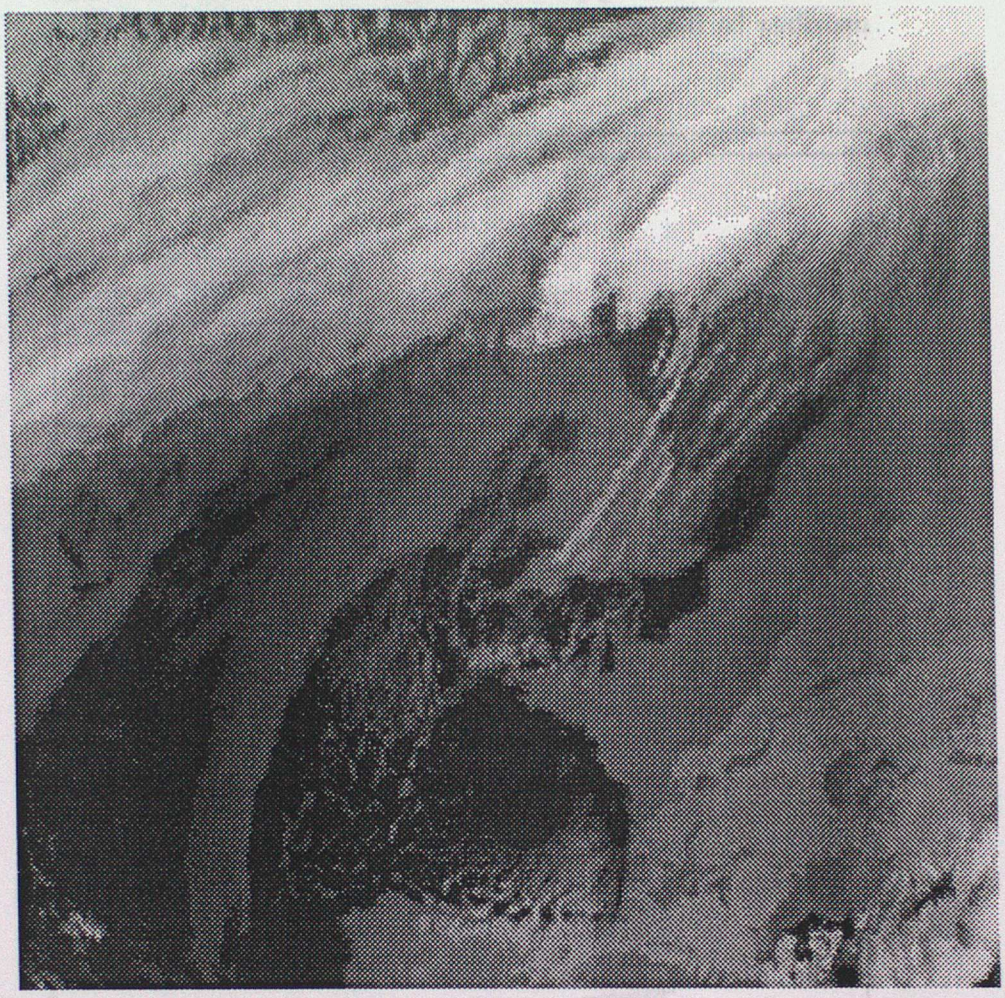


Figure 3: Deprojected image with repeated lines

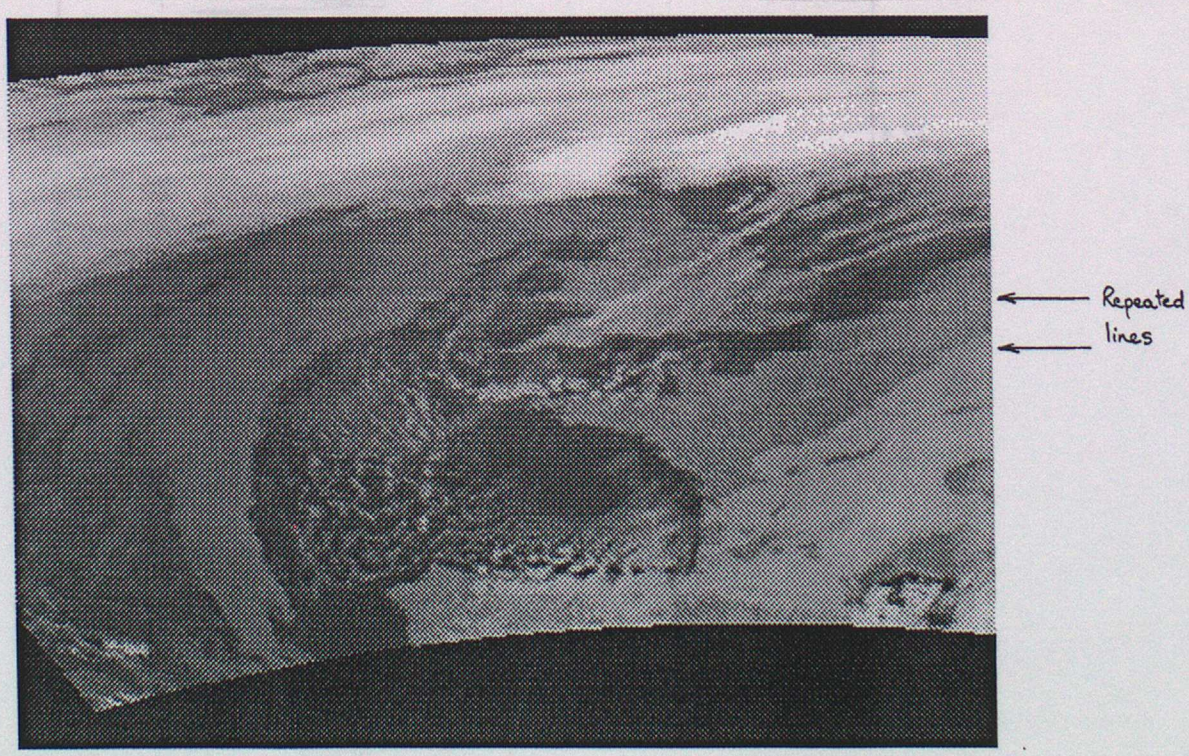
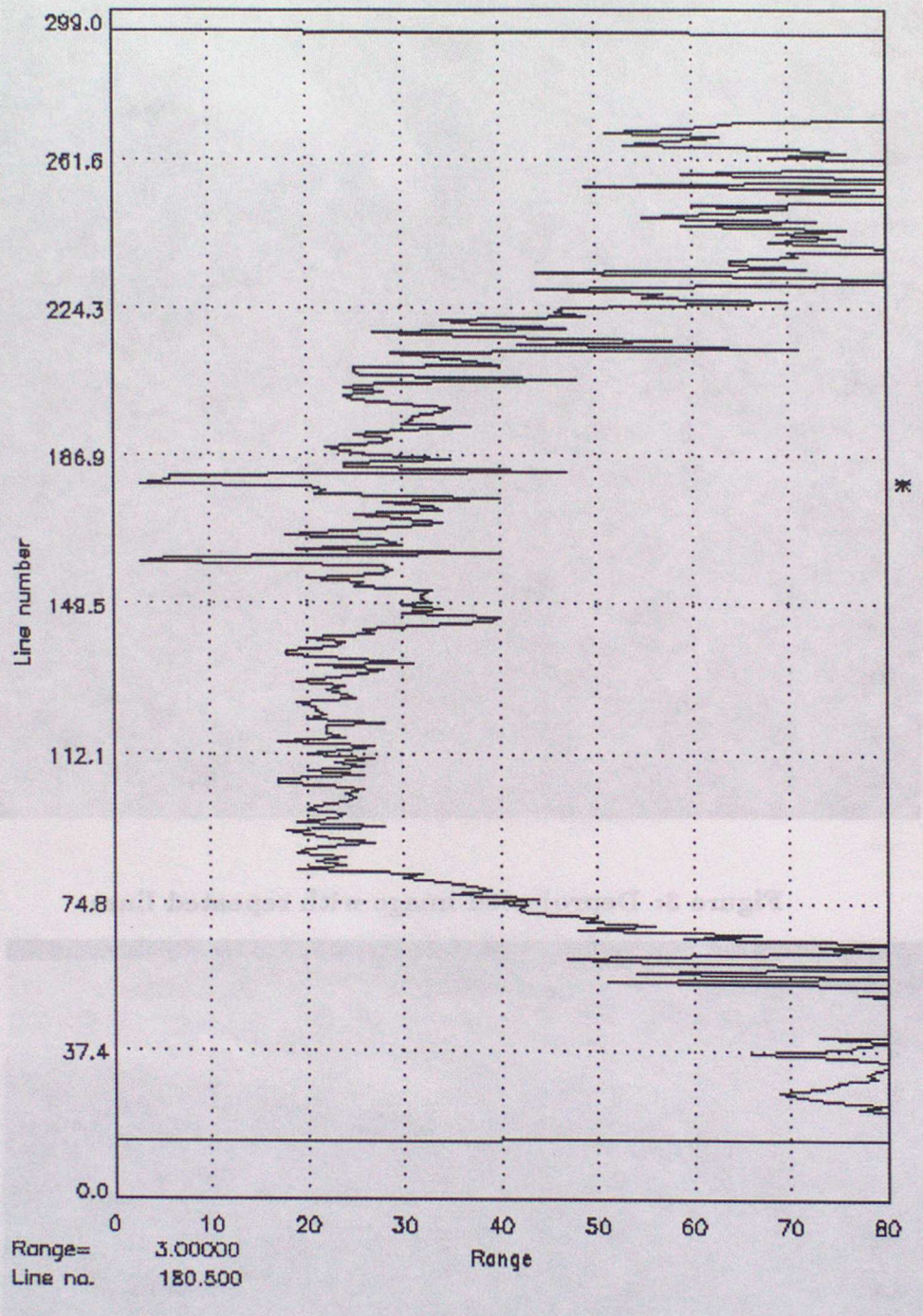



Figure 4: Plot of the range of the difference in pixel value for corresponding pixels in adjacent lines for each line number in image, showing two bursts of repeated lines.